Ultrasound massage application to decrease anesthetic spread in supraclavicular blocks

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I. Summary

Peripheral nerve blocks of the brachial plexus have become increasingly popular for performing upper limb surgery due to the benefits of using regional anesthesia instead of general anesthesia (Héroux et al., 2019; Lirk et al., 2018). When performing these blocks, the phrenic nerve is at risk of being affected by the anesthetic in the area, leading to a partial paralysis of the diaphragm on that side, also known as hemidiaphragmatic paresis (Ghodki & Singh, 2016). Ultrasound guidance has improved the quality of these blocks by giving providers the ability to visualize neurovasculature and the spread of anesthetic in real time (Koscielniak-Nielsen, 2008). This project aims to evaluate the use of ultrasound massage to mitigate the spread of local anesthetic.

II. Problem

The technique of using ultrasound massage to manipulate the spread of local anesthetic has not been tested in a supraclavicular block.

The specific aims of this study are:

Aim 1: To determine if ultrasound massage can be used to reduce the spread of local anesthetic.

Aim 2: To determine if dissection of the area is causing increased spread of local anesthetic.

III. Significance

The incidence of phrenic nerve palsy during a supraclavicular block has decreased since the introduction of ultrasound, but still remains between 50% to 67% (Renes et al., 2009). Because of this, there are still some reservations with using the technique in non-healthy patients.

Phrenic nerve palsy can result in ipsilateral hemidiaphragmatic paresis leading to respiratory distress in patients with preexisting respiratory conditions (Mak et al., 2001). Previous research has focused on the improvements ultrasound has made to the procedure, but little has focused on ultrasound massage of the area after administering the anesthetic. The results of this project will help providers decrease the incidence of phrenic nerve palsy resulting in a safer procedure that can be used on all patients and not just healthy patients.

IV. Background

Brachial plexus blocks are a popular way of anesthetizing the upper extremity for patients undergoing surgery. However, the brachial plexus block can be associated with high failure rates and increased incidences of local anesthetic systemic toxicity (Finucane, 2007). With the addition of ultrasound, brachial plexus blocks have become safer and more effective (Finucane, 2007; Sadowski et al., 2014). One of the benefits of using a peripheral nerve block is the increased safety of using regional anesthesia compared to general anesthesia alone (Héroux et al., 2019; Lirk et al., 2018; Wu & Fleisher, 2000).

Regional anesthesia is often used in conjunction with general anesthesia for procedures. With the addition of local anesthetic, the amount of general anesthesia is reduced along with the negative side effects commonly seen in patients. Local anesthetics are reliable sources of pain relief, or analgesic, and decrease the incidence of allergic reaction in patients when compared to general anesthesia alone (Lirk et al., 2018). Research has shown patients undergoing procedures with regional anesthesia have improved pain scores in the first seven days post-op than those undergoing procedures with general anesthesia alone (Héroux et al., 2019; Wu & Fleisher, 2000). A decrease in hypercoagulability, quicker recovery of GI function, decreased postoperative pulmonary mortality are also seen in regional anesthesia patients when compared to general anesthesia alone (Héroux et al., 2019; Wu & Fleisher, 2000). Different additives can be used to increase the duration of local anesthetics leading to a longer time to first opioid consumption (Héroux et al., 2019; Wu & Fleisher, 2000). Increased opioid use for pain relief has led to an opioid crisis in the United States, this type of anesthesia could aid in combatting the crisis. The positive effects of regional anesthesia are further seen when used in conjunction with ultrasound (Alfred et al., 2018; Riazi et al., 2008).

Ultrasound uses a transducer to emit sound waves to create an image using the pattern of electrical charges given off by return sound waves (Strakowski, 2015). The transducer can work with low frequency or high frequency sound waves (Strakowski, 2015). Lower frequency sound waves allow for deeper penetration, while high frequency sound waves allow for better resolution of superficial structures (Strakowski, 2015). The angle of the transducer corresponds with the amount of energy that can be reflected back, with more perpendicular application leading to a brighter image (Strakowski, 2015). The amount of energy reflected back is proportional to the difference in acoustic impedance between tissues (Strakowski, 2015).

The images created allow practitioners to identify nerves and tissues to diagnose compressive, demyelinating, and traumatic neuropathies (van Holsbeeck et al., 2020). Ultrasound doppler can be used to evaluate blood and fluid flow through tissue (van Holsbeeck et al., 2020). When contrast is added, ultrasound can be used for microvascularity images and blood perfusion in real time and provides a higher resolution of superficial nerves at a lower cost than MRI (van Holsbeeck et al., 2020; Walker, 2017). Ultrasound can also be used to diagnose motor diseases by visualizing fasciculations as they happen (Walker, 2017).

During procedures ultrasound allows practitioners to confidently identify structures in a particular area. Brachial plexus blocks occur in areas that contain several different vascular structures and nerve bundles (Sadowski et al., 2014; Perlas et al., 2009). Ultrasound gives practitioners the ability to visualize structures for better monitoring of needle location and anesthetic spread resulting in decreased needle punctures and pain scores after surgery (Barrington & Uda, 2018; Sites & Brull, 2006). This type of imaging can lead to decreased incidence of phrenic nerve palsy, pneumothorax and vascular injury when performing a brachial plexus block (Perlas et al., 2009; Finucane, 2007).

There are several different types of brachial plexus blocks that can be utilized depending on the area of the upper extremity that needs to be anesthetized (Baute et al., 2018). The supraclavicular approach is the most common way to accomplish anesthesia of the brachial plexus for performing surgeries of the arm, elbow, forearm, and hand (Sadowski et al., 2014). When performing a supraclavicular block, the patient is placed in a semi-reclined position with their head turned to the opposite side (Morfey & Brull, 2009). Anesthetists target the area lateral to the subclavian artery and superior to the first rib to ensure the local anesthetic surrounds the entire brachial plexus (Morfey & Brull, 2009). This approach provides anesthesia to the distal trunks and divisions of the brachial plexus (Mak et al., 2001). The phrenic nerve can be affected if the anesthesia travels superiorly along the fascial planes of the anterior scalene (Goyal & Jain, 2019; Mak et al., 2001). Involvement of the phrenic nerve during a brachial plexus block causes hemidiaphragmatic paresis (Hussain et al., 2020). This temporary paralysis of half of the diaphragm can result in respiratory distress in patients with pre-existing conditions (Ghodki & Singh, 2016; Mak et al., 2001). The use of ultrasound decreases the risk of phrenic nerve palsy due to the ability to see the structures in real time and visualize the spread of anesthetic (El-Boghdadly et al., 2017; Mak et al., 2001).

Ultrasound massage application to the area could allow for manipulation of the anesthetic. This technique uses the ultrasound probe to attempt to manipulate the spread of local anesthetic. Manual massage moves fluid into interstitial spaces to be incorporated into the lymph system (Watanabe et al., 2017). Previous studies have also found ultrasound can stimulate blood flow to an area (Handa et al., 2018.; Bansal & Padamkumar, 2011). Increasing blood flow in the area can lead to better uptake of molecules into surrounding tissues (Liu et al., 2021). Ultrasound massage aims to keep the local anesthetic from moving medially towards the phrenic nerve. This technique is commonly used by practitioners, but it has not been tested.

The visualization of anesthetic spread can also be viewed via radiograph or CT scan when the local anesthetic is combined with a contrast agent (Sasaki et al., 2017; Ponde et al., 2014). Using a radio-opaque additive with the local anesthetic, researchers are able to visualize the flow of the anesthetic in the area (Ponde et al., 2014). Radiograph can also confirm whether or not the needle was placed in the correct area by evaluating where the anesthetic is seen and comparing it to where it should be (Mehta & Salmon, 1985). However, using contrast agents to detect the spread using radiograph can lead to pathological damage if the contrast is not properly diluted (Sasaki et al., 2017). Monitoring the spread of anesthetic with radiograph also exposes the patient and provider to radiation that could be avoided when using ultrasound for visualization (McCartney et al., 2010; Harmon, 2007). Ultimately, using ultrasound has become the standard for better visualization during procedures due to the accessibility and the ease of identifying anesthetic spread (Harmon, 2007; McCartney et al., 2010).

Brachial plexus blocks provide multiple benefits in a clinical setting. As a form of regional anesthesia, the block decreases the amount of general anesthesia used thus reducing negative side effects, such as cardiac arrest, respiratory distress, brain injury, and anaphylaxis

(Héroux et al., 2019; Lirk et al., 2018; Wu & Fleisher, 2000). Through the use of ultrasound, brachial plexus blocks have become safer and more effective (Alfred et al., 2018; Barrington & Uda, 2018; Strakowski, 2015). The ability to view structures in real time has allowed practitioners to safely administer anesthetic and reduce the failure rate of brachial plexus blocks (El-Boghdadly et al., 2017; Perlas et al., 2009; Finucane, 2007). The ability to confidently identify structures and monitor the spread of anesthetic, while also reducing side effects, makes brachial plexus blocks a safe and reliable option for performing upper limb surgery.

However, brachial plexus blocks also carry the risk of phrenic nerve palsy. The phrenic nerve is the main motor supply for the diaphragm and receives contributions from the C3-C5 roots. The nerve runs across the anterior surface of the anterior scalene, from there it runs anterior to the second part of the subclavian artery and posterior the subclavian vein (Goyal & Jain, 2019; El-Boghdadly et al., 2017). The location of the phrenic nerve makes it susceptible to the spreading anesthetic used in supraclavicular brachial plexus blocks and can lead to hemidiaphragmatic paresis (Hussain et al., 2020; El-Boghdadly et al., 2017; Bigeleisen, 2003). Phrenic nerve palsy on one side does not affect most patients, but shortness of breath and respiratory distress can be seen in patients with preexisting respiratory conditions (Mak et al., 2001). These conditions can lead to decreased vital signs during surgery and an increased risk of cardiac arrest (Mak et al., 2001).

There has not been any previous research evaluating the effect of ultrasound massage on anesthetic in brachial plexus blocks. However, Robertson, T. (in progress) has examined the ability of ultrasound massage to increase the spread of anesthetic in sciatic nerve blocks. She found there was an increase in anesthetic spread in the group that received ultrasound massage strokes after injection when compared to the control group.

V. Research Design and Methodology

Section I: Research Aims and Hypotheses

Aim 1: To determine if ultrasound massage can be used to reduce the spread of local anesthetic.

H_1: Ultrasound massage will reduce medial spread of the local anesthetic.

Based on previous research performed by Robertson, T. (in progress), we expect ultrasound massage to affect the spread of the local anesthetic. Thus, using ultrasound massage to direct the anesthetic away from the phrenic nerve will be more effective than not using ultrasound massage.

Aim 2: To determine if dissection of the area is causing increased spread of local anesthetic.

H_2: When compared to C-ARM, dissection will cause a difference in the width and length of spread of anesthetic.

The local anesthetic is able to move along the fascial planes in the area of injection to reach the phrenic nerve. By dissecting to observe the anesthetic we are cutting through the fascial planes thus leading to an increase in the spread of anesthetic.

Section II: Materials & Data Collection

Twenty fresh-from-frozen cadavers will be used, with the right side of each cadaver being part of the control group (no massage) and the left side part of the experimental group (massage). Cadavers will be placed on a table that has been angled to 15 degrees. Using ultrasound, an anesthetist will identify the brachial plexus to perform a nerve blockade. Once identified, 15mls of a 25:75 mixture of methylene blue dye and 2% lidocaine will be injected from a lateral approach along the first rib. The injection site will be marked as a reference point for measurements of spread. The experimental group will immediately receive 5 inferiorly directed massage strokes with the ultrasound transducer.

After 15 minutes a dissection of the area will be performed to expose the spread of the anesthetic, taking care to identify the phrenic nerve and keep it intact. Part of the clavicle will be removed to allow for improved visualization. Using a digital caliper, the anterior, posterior, medial and distal spread of the anesthetic will be measured from the marked injection site. To prepare for data collection, brachial plexus dissection will be practiced on cadavers.

To compare the difference of anesthetic spread between dissection and C-ARM measurements, 10mls of methylene blue dye mixed with a contrast agent will be injected into the antebrachium of the cadaver. After 15 minutes, the C-ARM machine will be used to take measurements of the anesthetic spread. When these measurements have been collected, dissection of the area will be performed to measure the length and width of the spread using a digital caliper.

Section III: Data Analysis

To test the hypothesis for Aim 1, the measurements of the spread of anesthetic will be compared using Mann-Whitney U tests.

To test the hypothesis for Aim 2, the measurements will be compared using Wilcoxon signed-rank tests.

VI. Limitations

One of the limitations of the study is the use of cadavers to evaluate the spread of the anesthetic. The disadvantage of a cadaveric study is the lack of blood flow and interstitial flow to help carry the anesthetic in a specific direction. The interstitial flow contributes to the transport of molecules into surrounding tissue and massage application provides force to enhance this transport (Liu et al., 2021). Without this underlying flow in the cadaver, the spread of anesthetic would be different when compared to patients in the clinic. Another limitation of the study is the level of decomposition of the cadavers used. When specimens are obtained there can be a delay between collection and use causing some cadavers to be more decomposed than others. The level of decomposition could cause an increased or decreased spread of anesthetic compared to what is normally seen in a clinic.

VII. Chapters

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    a. Description of internship site
    b. Description of internship experience
    c. Journal summary

VIII. References

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